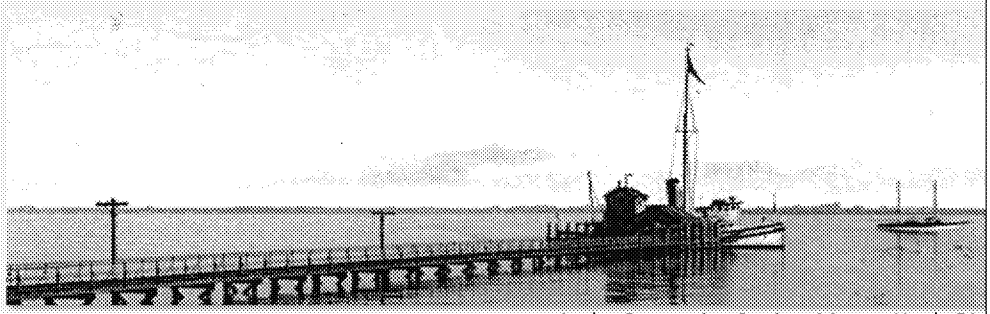
Development of an Atlantic sturgeon cohort model for the tidal-fresh Delaware River

James D Hagy III

US EPA Office of Research and Development
Center for Environmental Measurement and Modeling, Narragansett, RI

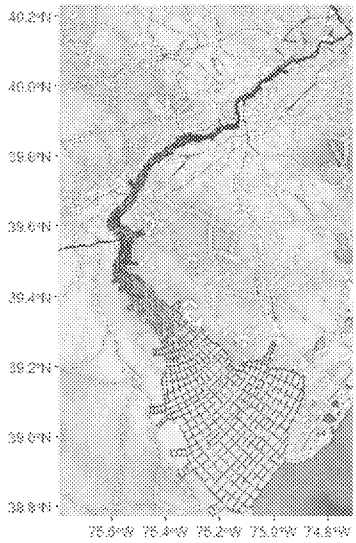


At the Quarantine Station, Marcus Hook, PA

Historical Photos from Facebook group "Marcus Hook Pictures"
https://www.facebook.com/groups/245264785598259/media

DRBC's EFDC/WASP model simulates realistic space/time data for water temperature, salinity, and dissolved oxygen throughout the river.

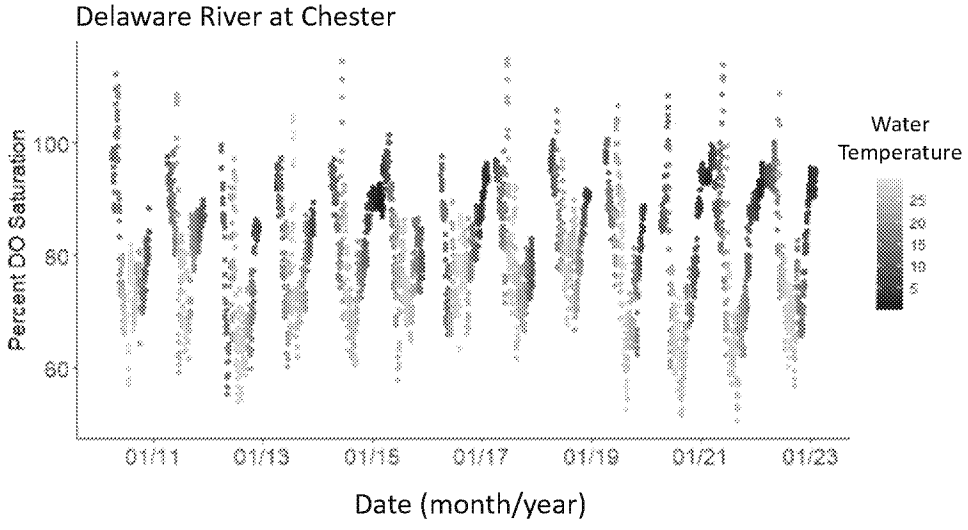
Delaware River EFDC/WASP Model
Source: DRBC



- 2019 Calibration Scenario
- HADO – "Highest Attainable Dissolved Oxygen" Scenarios
  - 2012
  - 2019

Draft / Pre-decisional

USGS/DRBC's continuous monitoring at several sites in the Delaware River quantify the range of water quality that occurs among years at those sites



Objective

Build a "tool" to translate observed and predicted water quality conditions in the Delaware River to expected growth and survival of juvenile (Age-0) Atlantic sturgeon

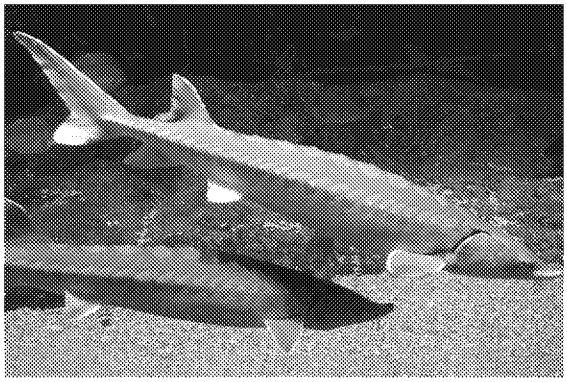
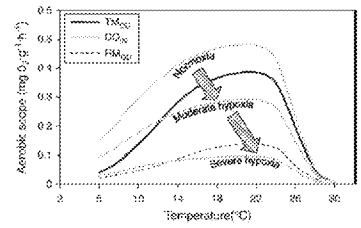
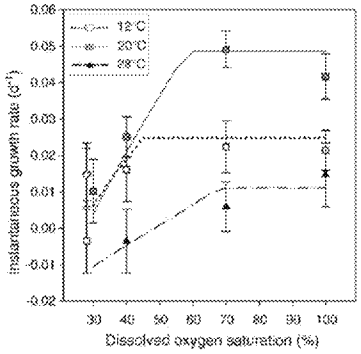


Photo: NOAA fisheries

Laboratory data and analysis using models describes the effect of water quality conditions on expected seasonal growth and survival of juvenile Atlantic sturgeon



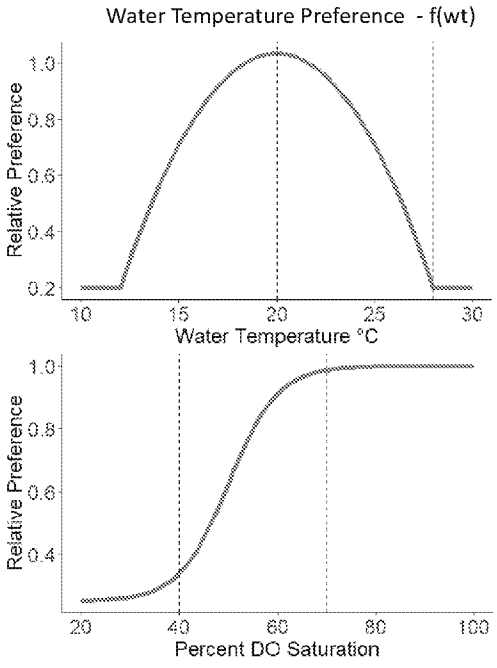


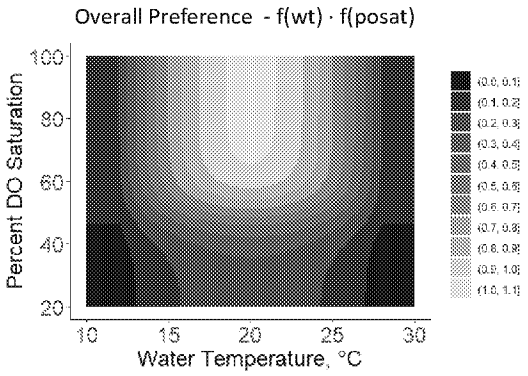
- Laboratory studies quantify effects of temperature and low oxygen on:
  - Growth (Niklitschek and Secor (2009a,b)
  - Survival (Secor and Gunderson 1998; Campbell and Goodman 2004; Niklitschek and Secor 2009a)
  - Habitat selection (Niklitschek and Secor 2010)
- A bioenergetics model combines data on T, S and DO effects on several bioenergetic rates to predict growth rate.

A population model was developed to predict growth and survival of juvenile Atlantic sturgeon using available exposure and response data

1. Predict **growth** rate using bioenergetic model developed by Niklitschek and Secor (2009).
2. Predict **mortality** due to low oxygen based on data from Secor and Gunderson (1998), Campbell and Goodman (2003), and Niklitschek and Secor (2009).
3. Simulate cohort growth and survival for 3 types of situations:
   a. Conditions over time at USGS/DRBC sondes
   b. Each "cell" of the DRBC model outputs
   c. Overall water quality in zones 3 and 4.
4. For simulations by zone, consider how fish behavior may affect water quality exposure.
5. Simulate a growth and survival of a cohort of juvenile sturgeon from July 1 to November 1

Choice tank study: Juvenile Atlantic sturgeon prefer water near 20°C vs. 28°C and DO at 70% vs. 40%



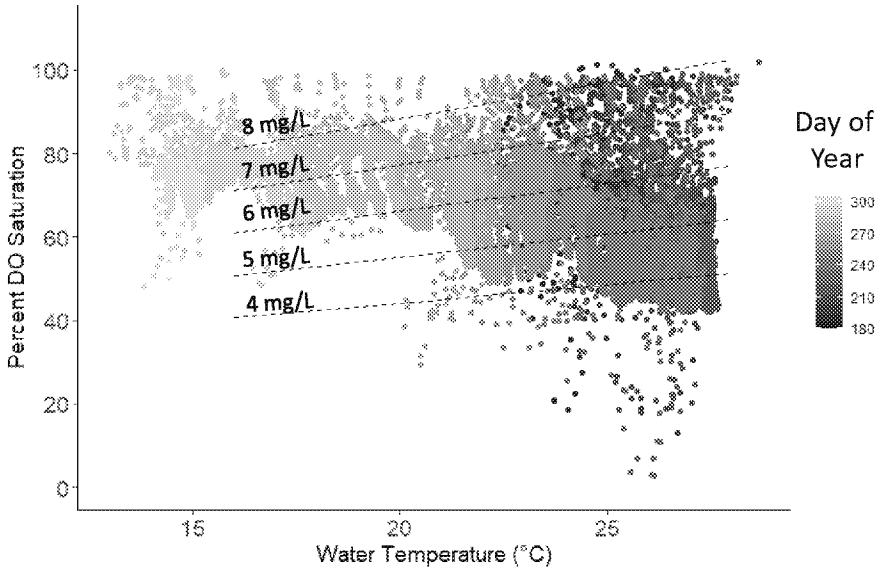


Fish rarely encounter a large spatial gradient in DO in a single day in zone 4. The effect of habitat preference on DO exposure is that zone small. For temperature, the effect is even less.

Based on Niklitschek and Secor (2010)

Draft / Pre-decisional

Percent DO saturation and water temperature combinations experienced by fish in 2019 Calibration scenario in Zone 4 from July 1 to November 1.



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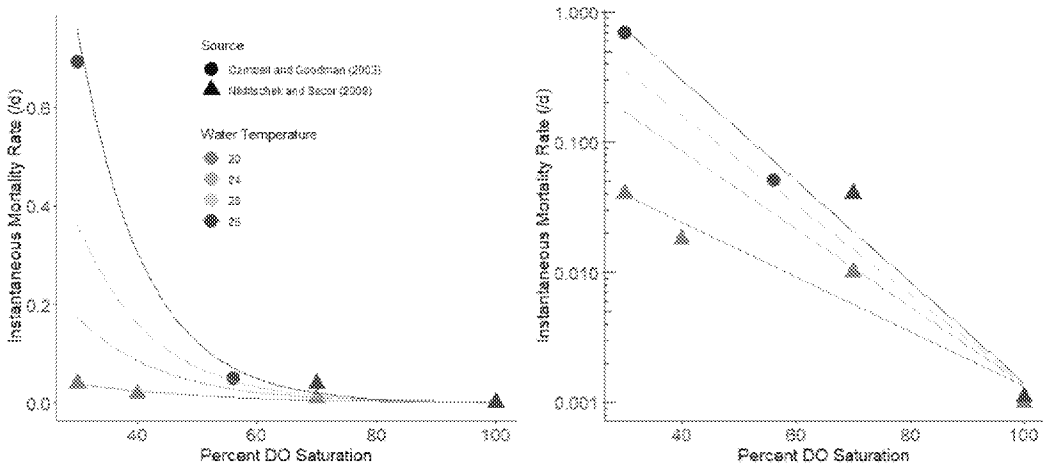
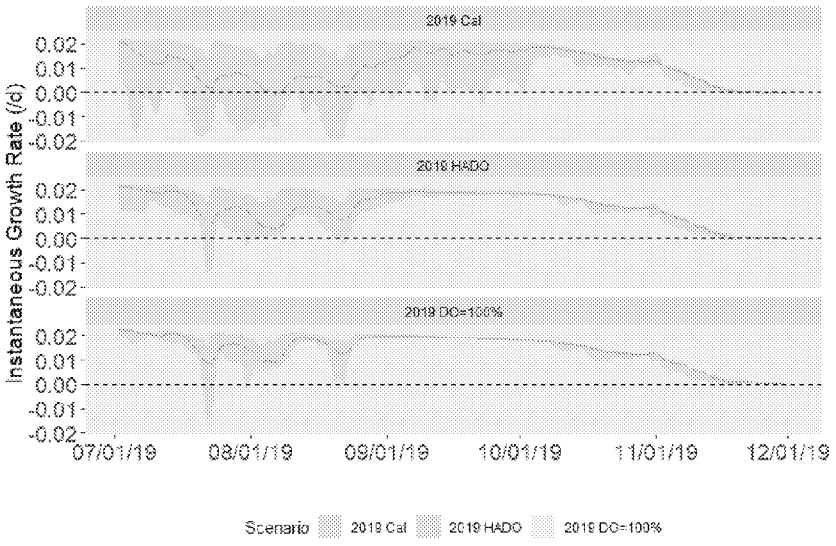
Estimated mortality rates due to low DO can be related to percent DO saturation and water temperature via a log-linear regression



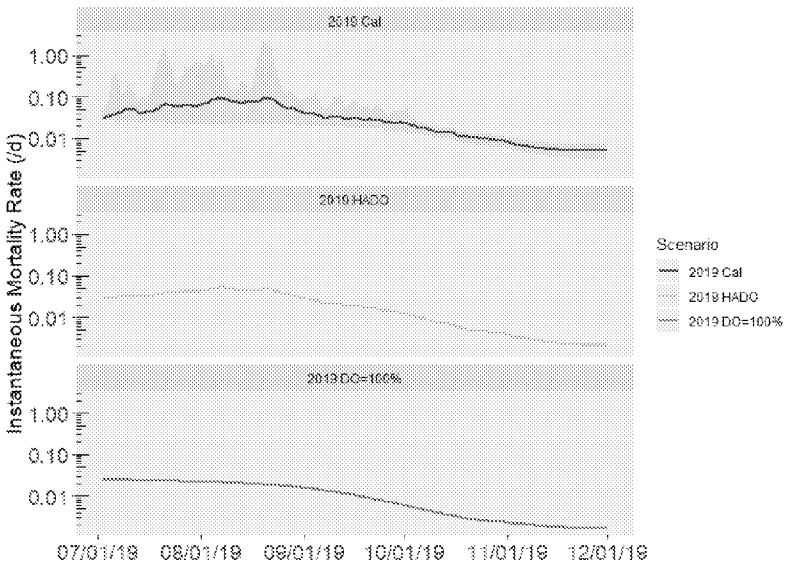
M=0.001 d^{-1} and 0.0011 d^{-1} were substituted for 0 to allow for log-transformation and graphical presentation

DO improvements in Zone 4 under the HADO scenario mostly eliminated periods with negative growth, but low DO still limited growth rate.



- POSAT = 100% is a diagnostic scenario … i.e., not based on any data or model simulation … shows rates with no DO impact.
- Therefore, focus on difference between scenarios.

Under the 2019 HADO scenario, mortality due to low DO was much less than in the 2019 Calibration, but low DO still caused some mortality.



Mortality in POSAT = 100% diagnostic scenario is background rate, which decreases with increasing fish size.

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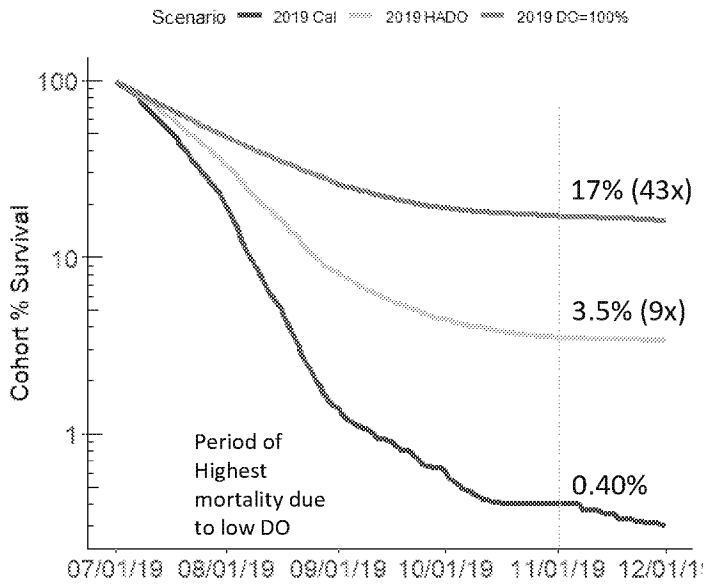
The HADO scenario resulted in 9-fold greater abundance of the cohort on Nov 1, but mortality due to low DO still occurs.



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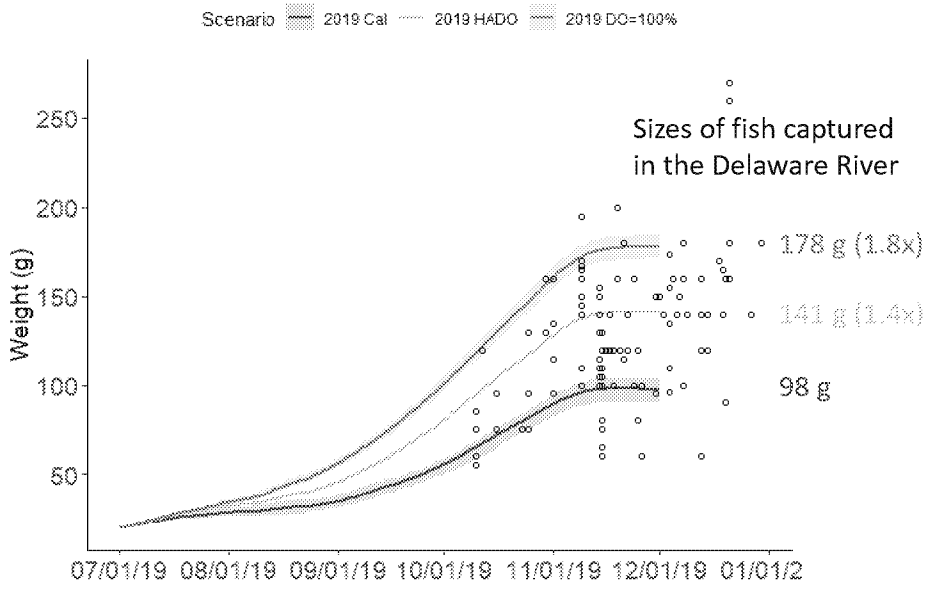
The effects of higher DO on juvenile growth are 10-20x less than the effects of DO on survival



Fish data from Ian Park (DNREC)

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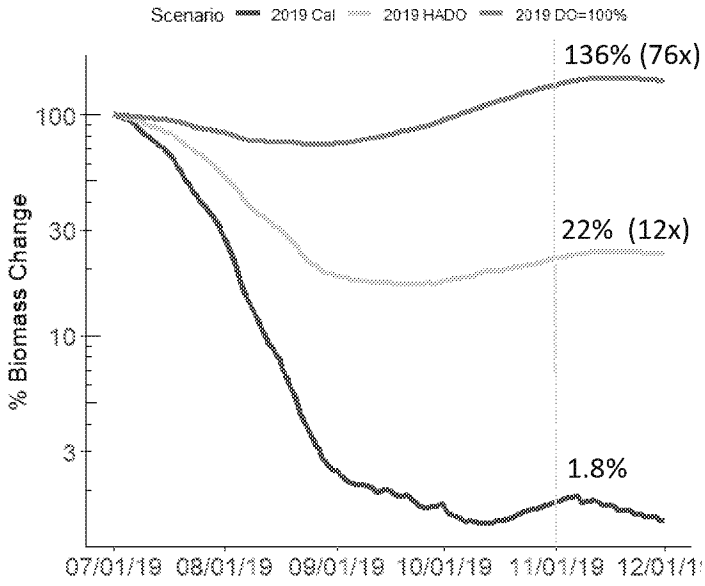
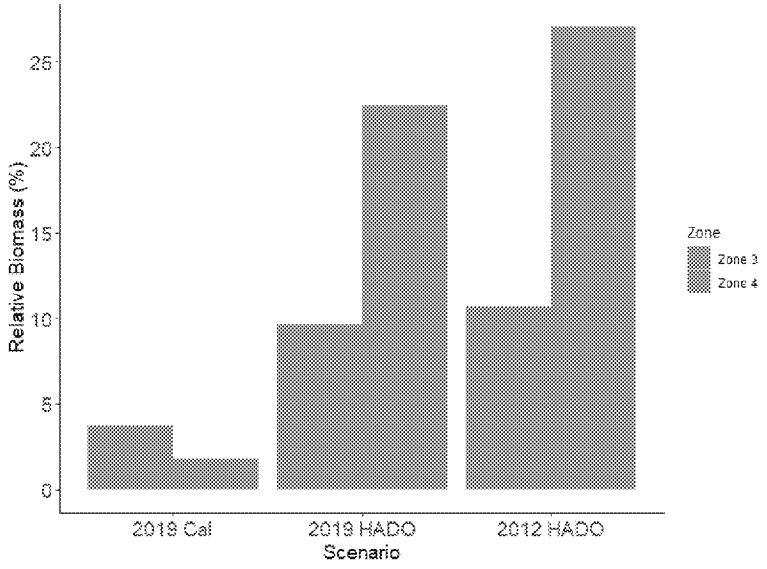
The effects of higher DO on cohort biomass reflect both growth and survival



Growth and survival was higher in Zone 3 in the 2019 Calibration, but improvement with HADO was greater in Zone 4.



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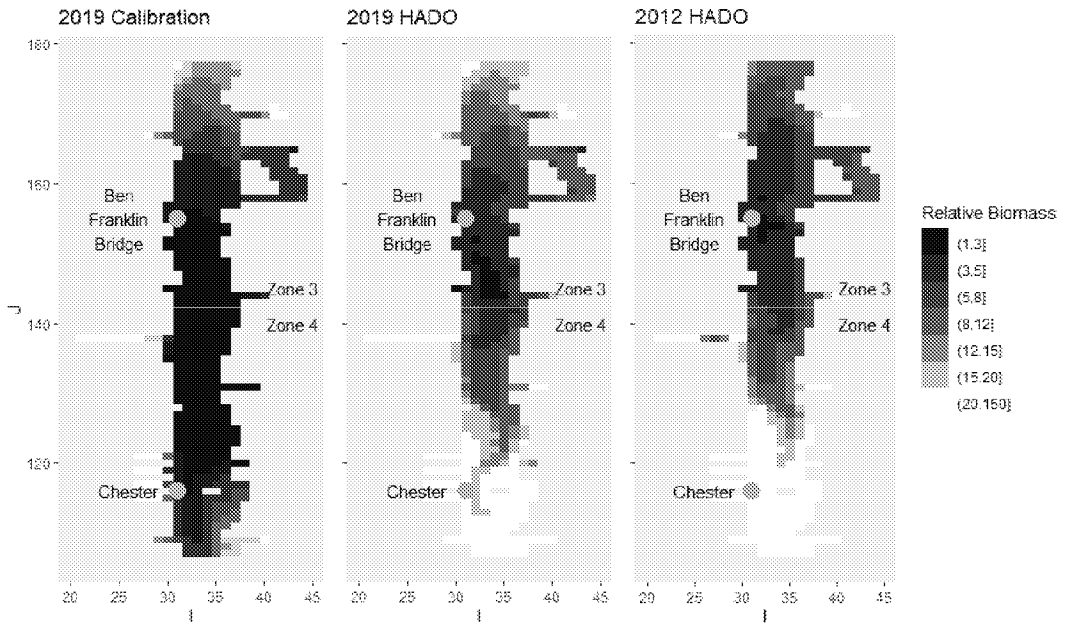
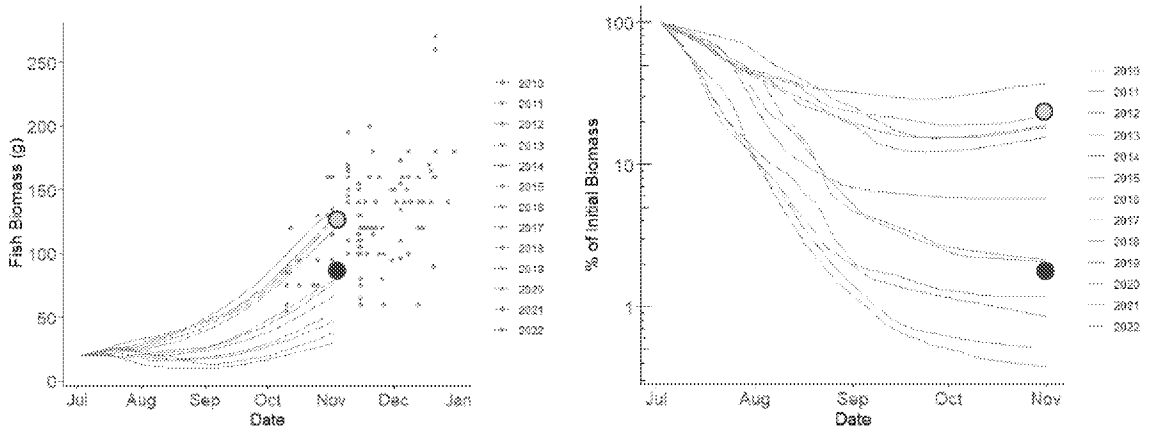
Growth and survival of juvenile Atlantic sturgeon is spatially structured. Increases in zone 4 with HADO scenario reflect increased DO overall and up-river shift



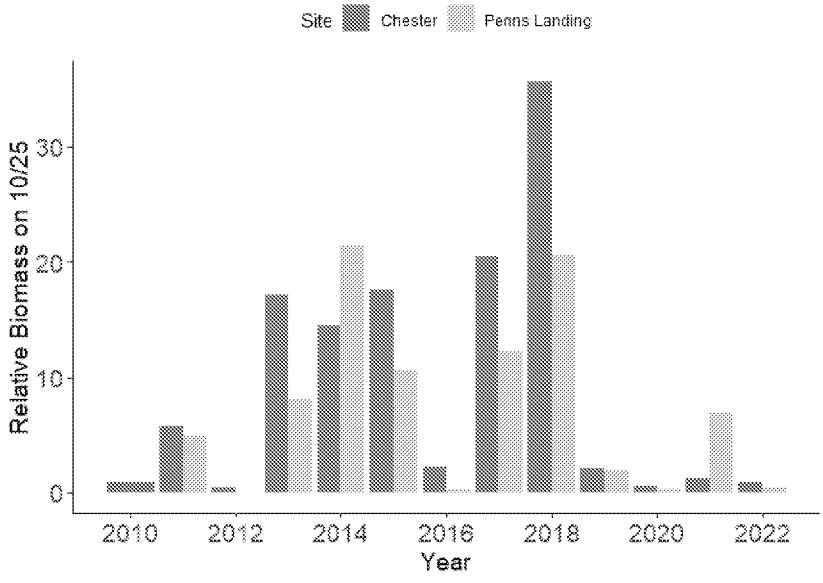
The cohort model predicts a large range of outcomes in association with water quality observed at Chester, PA

- 2019 HADO scenario for zone 4 produced cohort outcomes like the better years in the Chester time series



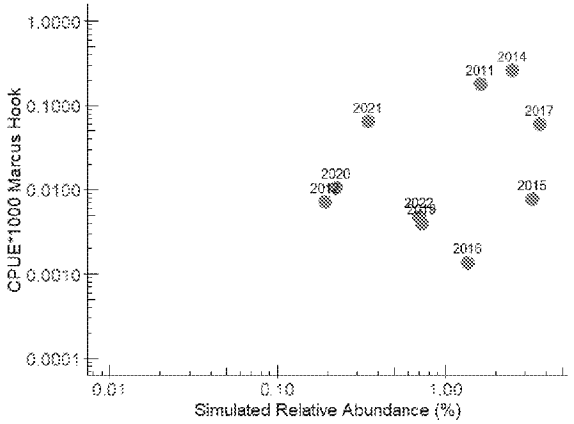
● 2019 Calibration ○ 2019 HADO Scenario

Growth and survival predicted by the cohort model was usually higher for Chester than Penn's Landing, and years with favorable conditions saw better outcomes at both sites

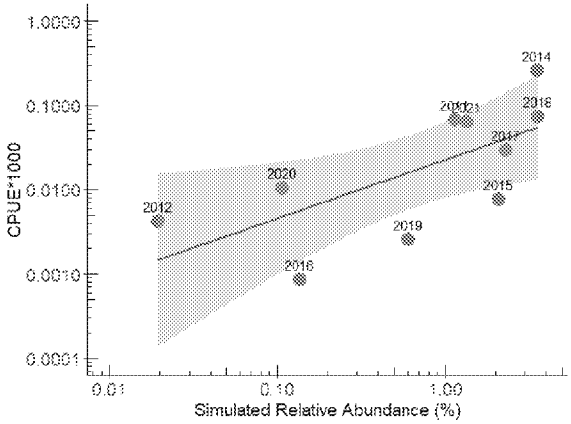


Comparison of simulated growth and survival with CPUE is variable… better correlated for Penns Landing

Simulation for Chester vs. Marcus Hook YOY CPUE

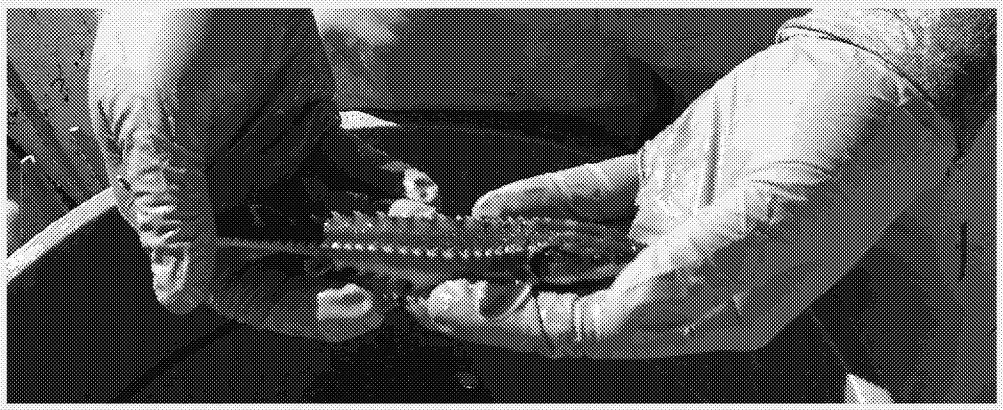


Simulation for Penns Landing vs. YOY CPUE



Conclusions

- The cohort model, although grounded in **laboratory data**, produces results **consistent with field observations** and is a useful **tool for interpreting** these data in the context of spatial and temporal water quality variability.
- The **effect of low DO on survival was quantitatively larger** than its effect on growth. However, both growth and abundance effects have been observed in data from the fish population (reported by Ian Park)
- Simulations highlight differences between the calibration and HADO management scenarios at the scale of Zones, showing **increased Atlantic sturgeon growth and survival under HADO**.
- Diagnostic simulations show that DO would likely continue to limit Atlantic sturgeon in Zone 3 and 4 under the HADO scenario.
- Simulations highlight **spatial structure** of low DO in all model scenarios and their implications for growth and survival of juvenile Atlantic sturgeon.
- Model predictions highlight that **interannual variability** in water quality observed at Chester and Penn's Landing would be expected to cause large differences in Atlantic sturgeon growth and survival, **consistent with juvenile abundance data**.



This juvenile Atlantic sturgeon was caught on 10/14/2016 at Marcus Hook. It has a total length of 195 mm and weighed 30 grams. Photo by Ian Park. Collection of protected species for scientific purposes conducted under permit number 19255.